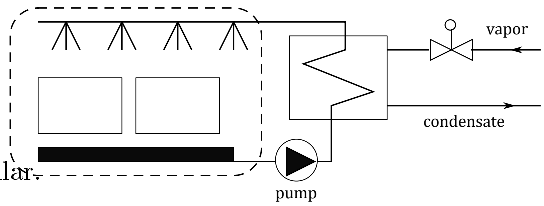
Thermal processes

Autoclave for food sterilization under pressure consists of 0.8 t potato and 0.35 t water. Autoclave construction weight is 1.2 t. The autoclave is heated by the steam which consumption is adjustable (signal $0-100\%$) between $0\ldots 1300\ kg/h$.

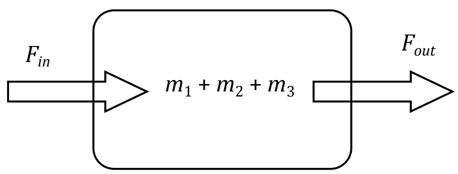


Specific heat capacities: of water 4.18 and iron 0.44 $kJ/(kg\cdot^{\circ}C)$, water heat of evaporation is 2256 kJ/kg, potato and water properties are similar.

With 10% of steam consumption autoclave reaches the temperature of 97 $^{\circ}C$ (if temperature of environment $T_e = +22\ ^{\circ}C$).

1. Provide an equation describing thermal process.
2. What is the time constant T_s of the autoclave?
3. Does the autoclave temperature can rise faster than 7.5 $^{\circ}C/min$?
4. Steam inflow was closed at 95 $^{\circ}C$
   - How fast temperature decreases?
   - What is the temperature of autoclave in 1 h and 30 min?

Comments



iron + water + potato

Q - quantity of heat

$F = \mathrm{d}Q/\mathrm{d}t$ - heat flow

T - autoclave temperature

T_e - environmental temperature

$\mathrm{d}Q/\mathrm{d}t = F_{in} - F_{out}$ - thermal process in autoclave

1. Autoclave consists of 3 materials (iron, water, potato) with a temperature T

   quantity of heat in the autoclave is

   $$Q = Q_1 + Q_2 + Q_3 = (c_1 m_1 + c_2 m_2 + c_3 m_3)T = \sum c_i m_i \cdot T$$

   process equation

   $$\mathrm{d}(\sum c_i m_i \cdot T)/\mathrm{d}t = P - K(T - T_e),$$

   where P - power given by steam, $K(T - T_e)$ - cooling into environment

   steam temperature is 110 $°C$, autoclave temperature rate is $22 \ldots 97$ $°C$

2. Steam inflow power P does not depend on the temperature T of the autoclave

   Why is that? Cooling process depends on the temperature T: $-K(T - T_e)$

   During steam condensation all obtained heat is transferred into circulating water condensate

   Let the circulation flow is 10 l/s, how much changes the temperature ΔT with the maximum steam consumption?

   $$F_{in} = P = c_e q_s = c_w q_w \Delta T,$$

   where P =const until $T < T_{steam}$

   What happens if autoclave temperature is > 100 $°C$ (or $\approx T_{steam}$)?

3. We can use another variable "higher temperature" $\theta = T - T_e$

   $$\sum c_i m_i \cdot \mathrm{d}\theta/\mathrm{d}t = P - K \cdot \theta,$$

   temperature rise speed is $\mathrm{d}\theta/\mathrm{d}t = \ldots (\theta = 0)$

4. steady-state $P = K(T - T_e) = K \cdot \theta \quad \rightarrow \quad$ gain $K = \ldots$ kW/K

5. cooling ($P = 0$) $\sum c_i m_i \mathrm{d}\theta/\mathrm{d}t = -K \cdot \theta$
   and the process
   $$\theta(t) = \theta_0 \cdot e^{t/T}$$